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12 **Unexamined Patent Application**

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54 Method for Data Transmission and Device for Data Transmission

57 The invention relates to a method for transmitting data between a base station (1) and a plurality of mobile stations (2) over radio channels (3), with the respective data streams being differentiated in a code. The signals are pre-equalized in a modulator (4) in which the transmission characteristics of all radio channels (3) and the different codes of all radio channels (3) are taken into account (Figure 3).\

[see source for figure]

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Description

Prior Art

The invention relates to a method and to a device according to the species of the independent claims. From an article by A. Klein, G. K. Kaleh, and P. W. Baier, "Zero Forcing and Minimum Mean Square Error Equalization for Multiuser Detection in Code Division Multiple Access Channels," IEEE Trans. Vehic. Tech., Vol. 45 (1996), pp. 276-287, methods are already known that take into account the so-called intersymbol interferences (ISI) between data symbols of a user as well as multiple-access interferences (MAI), that is, interferences from other users, in a radio data receiver. All transmission interferences are thus taken into account at the receiver. When such methods are used in mobile telephone systems or mobile radio systems, the individual mobile stations are very costly due to the fact that this method places high technical demands on the receiver.

Advantages of the Invention

The method according to the invention or the device according to the invention, in contrast, has the advantage that all interferences that can appear via the radio transmission are taken into account at the transmitter. The data receivers may thus be constructed with a particularly simple design.

This is especially advantageous for the transmission of data from a base station to a plurality of mobile stations. A method or a device may be used for the back-transmission which takes into account all interferences on the receiver side, so that the individual mobile stations of a mobile telephone system may be constructed with a particularly simple design. However, the method according to the invention or the device according to the invention may also be used for data transmission from mobile stations to base stations. It is particularly simple to measure the transmission quality or the channel impulse response in the base station, and from that point the results may optionally be distributed.

Drawings

Embodiment examples of the invention are explained in more detail in the following description. **Figure 1** shows the general design of a mobile radio system or a mobile telephone system, **Figure 2** shows a conventional system according to the prior art, **Figure 3** shows the inventive data transmission from a base station to a mobile station, and **Figure 4** shows the inventive data transmission from a mobile station to a base station.

Description

Figure 1 schematically depicts a radio cell of a cellular mobile telephone system or mobile radio system having a base station **1** and a plurality of mobile stations **2**. In this system it is essential that exchange of data occurs only between base station **1** and mobile stations **2**, and that no direct data exchange is possible between mobile stations **2**. Base station **1** is also designated as a central station, and mobile stations **2** are also designated as peripheral stations. Data are exchanged between base station **1** and mobile station **2** by radio transmission. The radio transmission from base station **1** to a mobile station **2** is designated as downlink, and data transmission from a mobile station **2** to base station **1** is designated as uplink. For such a system represented in **Figure 1** having a central or base station **1** and a plurality of peripheral or mobile stations **2**, it is to be determined how the data for the different mobile stations are modulated so that said data can be separately detected in the receivers of the different mobile stations. The system according to **Figure 1** is a so-called CDMA (code division multiple access) system in which a common frequency band is available for the data transmission, with the individual data channels between base station **1** and the respective mobile stations **2** being differentiated with respect to a code with which the signal for the corresponding mobile station **2** is spread. By means of this spreading with the code, each signal that is intended to be exchanged between base station **1** and a specified mobile station **2** is distributed over the entire available spectrum. Each individual information bit to be transmitted is thus broken down into a plurality of small "chips." The energy of a bit is thereby distributed over the entire frequency spectrum that is available to the CDMA system.

information, for example, user **8** is a voice decoder, and for other data, the user is a computer or fax machine, for example. Mobile stations generally have only a single data user **8**, and therefore have only a single data stream. For a completely undisturbed transmission over radio channel **3**, demodulator **7** would need to identify only the code information of the data to be detected for user **8** in order to perform demodulation. However, because of the aforementioned interferences, this is not sufficient. To take ISI into account, a channel estimator **10** is necessary to provide information on the transmission characteristics, that is, the channel impulse response of radio channel **3**, for the affected mobile station **2**. To compensate for MAI, mobile station **2** must also know all codes used in the base station. For this purpose a code generator **9** is provided which, in addition to the code information on the data to be detected here, supplies code information on all codes used in the system. This method is also known as "joint detection." Mobile stations that are designed to receive data from base station **1** in this manner are relatively costly.

The method according to the invention and the device according to the invention are explained in more detail with reference to **Figure 3**, which also shows the downlink transmission from a base station **1** to a mobile station **2**. In **Figure 3**, base station **1** also has a modulator **4** which creates the transmission signals for an antenna **100** of base station **1**. Modulator **4** receives a plurality of data streams from data sources **6**, and the data streams are spread with code information from a code generator **5**. A channel estimator **11** is also provided which supplies information on the transmission characteristics of all radio channels **3**. Modulator **4** creates a transmission signal here which takes into account both the ISI and the MAI. The transmission signal is designed in such a way that upon reception, each of the mobile stations **2** receives an interference-free signal (provided that this is possible). Interferences which originate from the simultaneous use of a plurality of codes as well as interferences which originate as a result of the transmission characteristics of the individual radio channels are taken into account. Thus, the data receiver [in] mobile station **2** in **Figure 3** has a correspondingly simple design. The mobile station has a demodulator **7** which receives the signal from antenna **100**. Only the code information for the affected data stream from a code generator **9** need be provided to demodulator **7**, and from this code information, demodulator **7** then creates the data stream for data user **8**. These mobile stations thus have a particularly simple design.

In **Figure 3** it was shown that during downlink transmission all interferences of the radio channel in the transmitting station, and thus during downlink transmission in the base station, are

taken into account. The downlink portion of mobile station **2** can therefore be constructed with a particularly simple design. In order to keep mobile stations **2** simple for the uplink path as well, that is, for the transmission of data from mobile station **2** to base station **1**, the method corresponding to **Figure 2** could be used for this transmission in which the ISI and MAI in the receiving station, that is, again in the base station, are taken into account. Such a system in which the mobile stations have a particularly simple design is made possible by the fact that ISI and MAI are taken into account only in the base station. In a corresponding TDD system it is also very simple to obtain the channel transmission characteristics by means of channel estimator **11** in base station **1,** in that the characteristics of the respective transmission channels may be determined by evaluating the received uplink data in the base station. Furthermore, the channel impulse response or channel quality may also be communicated by a data telegram from the mobile station to the base station.

The method according to the invention may also be used to transmit data from mobile station **2** to base station **1**, as represented in **Figure 4**. Mobile station **2** is shown here in uplink, that is, with modulator **4** which edits a data stream of a data source **6**. To take into account the transmission characteristics of all radio channels **3** and codes used in the system, a code generator **5** is provided which sends to demodulator **4** the code information for all codes used in the system, and a channel estimator **11** is provided which sends the transmission characteristics of all radio channels. It is possible for base station **1** to supply information on the transmission characteristics of all channels to mobile station **2**. The interferences from multipath transmission from radio channel **3** and from simultaneous transmission of a plurality of data streams during generation of the radio signal are taken into account in modulator **4**. The radio signal is transmitted over antenna **100** and radio path **3** to base station **1**. Base station **1** receives not only the data from mobile station **2** as shown in **Figure 4**, but at the same time also the radio signals from other mobile stations, not shown in **Figure 4**. Code generator **9** correspondingly passes on to demodulator **7** of base station **1** all code information and decodes a plurality of data streams for a plurality of data users **8**. However, it is no longer necessary here to provide a channel estimator for decoding.

The method by which the transmission characteristics of all radio paths (ISI) and the codes of all radio paths (MAI) are taken into account is described hereinafter by mathematical formulas.

These formulas may be employed either by an appropriate program or by appropriate hardware components which implement these formulas.

First Example

Point to Multipoint Transmission

This example corresponds to **Figure 3**, that is, to the transmission from a base station **1** to a plurality of mobile stations **2**, with only one mobile station being shown in **Figure 3** for illustrative purposes.

A discrete-time multiple transmission system having block-by-block transmission will be assumed. If $\underline{d}^{(k)} = (d^{(k)}, \ldots, d^{(k)}M)$, then k =1, . . ., K is the vector of M data symbols of a data block of the kth user to be transmitted. $d = (\underline{d}^{(1)}, \ldots, \underline{d}^{(K)})$ denotes the combination of all data symbols to be transmitted. To each of the K users K = 1, . . ., K is assigned a CDMA code $\underline{c}^{(k)} = (c^{(k)}, \ldots, c^{(k)}{}_Q)$, of length Q. By using CMA codes to spread the data bits to be transmitted, each bit is distributed over Q so-called chips. One chip clock period is exactly 1/Q of the bit clock period. With the code matrix

[see source document for formula]

$\underline{c}^{(k)\tau}$ = transported vector $\underline{c}^{(k)}$

of the kth user, the spreading of a data block of the kth user may be written as:

[see source document for formula]

The entire block of M data bits is thus distributed over M · Q chips. The succession of chip clock signals of all users is obtained as

[see source document for formula]

where the matrix

[see source document for formula]

combines the code matrices of all users.

After modulation, the signals are linearly pre-equalized according to the invention. In **Figures 3** and **4**, the modulation steps which here are treated mathematically separate from one another are achieved by equalization by modulator **4**. The equalization may be described by matrix P:

[see source document for formula]

The impulse response of the kth transmission channel with respect to the chip clock frequency may be expressed as $\underline{h}^{(k)} = (h_1^{(k)}, \ldots, h_w^{(k)})$. W is the number of chip clock periods over which a multiple path reception is taken into account. The data blocks of chip clock length $M \cdot Q$ are extended to $M \cdot Q+W-1$ via the multiple path channel. The last $W-1$ chip clocks thus overlap the first $W-1$ chip clocks of the next data block. The kth demodulator generally receives, in addition to the multipath signal, additive noise $\underline{n}^{(k)} = (n^{(k)}, \ldots, n^{(k)}_{M \cdot Q+W-1})$ of length $M \cdot Q+W-1$. By the matrices

[see source document for formulas]

the kth demodulator of the system thus receives the signal

[see source document for formula]

Matrix D sums the pre-equalized chip clock signals of all users in order to emit said signals via an antenna.

A suitable demodulator corresponding to **Figure 3** may be designed as a simple "matched filter" which despreads the received chip clock signal with the CDMA codes of the desired data signal. This "matched filter" receiver (1-finger rake receiver) for the kth user code $\underline{C}^{(k)}$

[see source document for formula]

demodulates the received signal to give

[see source document for formula]

$R^{(k)H}$ = conjugated transported matrix $R^{(k)}$
With the combinations

[see source document for formulas]

the following is obtained as the total vector of all demodulated signals:

[see source document for formula]

The $M \cdot K \times M \cdot Q \cdot K$ matrix $R^H \cdot H \cdot D^\tau \cdot D$ generally has the rank $M \cdot K$. Thus, $(R^H - H - D^\tau - D) \cdot (R^H \cdot H \cdot D^\tau \cdot D)^H$ may be inverted, giving

[see source document for formula]

This choice gives

[see source document for formula]

R^H thus sends the transmitted data symbols d^τ and additive noise. Despite the use of a very simple receiver, the detented signal contains neither ISI nor MAI. These interferences are eliminated on the transmitter side by pre-equalization.

Second Example

Multipoint to Point Transmission

This embodiment example corresponds to **Figure 4**.
Using the designations of the first embodiment example, in addition to

[see source document for formula]

and P' = pre-equalizer matrix for multipoint to point transmission,
the “matched filter” receiver R^H demodulates the total received signal to give

[see source document for formula]

The choice of

[see source document for formula]

here as well gives:

[see source document for formula]

Claims

1. Method for transmitting data between a base station (1) and a plurality of mobile stations (2) over radio channels (3), the data from different mobile stations being spread with different codes, **characterized in that** the signals to be transmitted are pre-equalized in a modulator (4), and that the transmission characteristics of all radio channels (3) and all the different codes are taken into account during pre-equalization.

2. Method according to Claim 1, characterized in that data are transmitted from a base station (1) to a plurality of mobile stations (2).

3. Method according to Claim 1, characterized in that data are transmitted from a plurality of mobile stations (2) to a base station (1).

4. Method according to one of the preceding claims, characterized in that the transmission characteristics of the radio channels (3) are determined by the base stations (1) from data transmissions from the mobile stations (2) to the base station (1).

5. Device for transmitting data over at least one radio channel, the device being used in a system which connects a base station and a plurality of mobile stations over radio channels (3), and the data from different mobile stations being spread with different codes, characterized in that a modulator (4), a code generator (5), and a channel estimator (11) are provided, and that the modulator (4) performs pre-equalization based on information from the code generator (5) and the channel estimator (11).

6. Device according to Claim 5, characterized in that data are transmitted from a base station (1) to a plurality of mobile stations (2).

7. Device according to Claim 5, characterized in that data are transmitted from a plurality of mobile stations (2) to a base station (1).

8. System for transmitting data over at least one radio channel (3) with a base station and a plurality of mobile stations, the data from different mobile stations being spread with different codes, characterized in that a modulator (4), a code generator (5), and a channel estimator (11) are provided, and that the modulator (4) performs pre-equalization based on information from the code generator (5) and the channel estimator (11).

9. System according to Claim 8, characterized in that the transmission characteristics of the radio channels (3) are determined by the base stations (1) from data transmissions from the mobile stations (2) to the base stations (1).

Two pages of drawings are attached hereto.

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[see source for figures]

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[see source for figures]